

NASW-4435

1N-54-CR

73904

P. 40

NASA/USRA

UNIVERSITY OF IDAHO

**EXERCISE/RECREATION FACILITY
FOR A
LUNAR OR MARS ANALOG**

JUNE 1991

(NASA-CR-189993) EXERCISE/RECREATION
FACILITY FOR A LUNAR OR MARS ANALOG Final
Report (Idaho Univ.) 40 p CSCI 06K

N92-25161

Unclas

G3/54

0073904

ABSTRACT

The University of Idaho, NASA/USRA project for the 1990-91 school year was to design an exercise/recreation station for an earth-based simulator of a Lunar or Mars habitat. Specifically, we designed a stationary bicycle that will help people keep fit and prevent muscular atrophy while stationed in space. To help with motivation and provide an element of recreation during the workout, the bicycle is enhanced by a virtual reality system. The system will simulate various riding situations, including the choice of a mountain bike or road bike. The bike employs a magnetic brake that provides continuously changing tension to simulate the actual riding conditions. This braking system will be interfaced directly with the virtual reality system. Also, integrated into the virtual reality display will be a monitoring system that regulates heart rate, work rate, and other functions during the course of the session.

TABLE OF CONTENTS

INTRODUCTION	1
Psychological Effects of Long Duration Space Flight	1
Entertainment Methods	4
EXERCISE/RECREATIONAL FACILITY	5
Constraints of the Facility	5
Identifying the Users	6
Equipment in the Facility	6
Functions of the Equipment	7
Requirements of the Equipment	7
Muscle Groups	8
Exercise Methods	9
FINAL EQUIPMENT SELECTION	11
Exercise Bike	11
Virtual Reality System	12
RIDING SYSTEM	12
The Bike	13
The Handlebar Assembly	14
The Tilting Mechanism	15
Resistance Mechanism	16
The Harness	16
Bike/VR/User Interface	17
Cost Analysis	18
CONCLUSIONS AND RECOMMENDATIONS	18
BIBLIOGRAPHY	19
Appendix A Trek 1420	21
Appendix B Handlebar Assembly and Mounting	24
Appendix C Tilting Mechanism	28
Appendix D Harness System	32
Appendix E Calculations	34

INTRODUCTION

With the proposed plans to have permanent manned stations on the Moon or Mars, it is vital to have facilities that help keep the crew members in shape both physically and psychologically. An extensive literary study was conducted on the physical effects of long duration space flight as well as the psychological effects of isolation and confinement. Also, several interviews were conducted with people who have "wintered over" in Antarctica and are familiar with the type of living environment that would exist on a Mars mission. From this research, it is shown that serious muscle atrophy results from living in microgravity for long durations, and ill psychological effects due to isolation and confinement can occur. Our project was to develop a facility, which will be tested in an Earth-based simulator of a Lunar or Mars habitat, to overcome these problems. Several types of entertainment and exercises have been developed that could be incorporated into the exercise/recreation facility to maintain the crew members' well being. This paper gives a summary of this research, and describes an exercise bike with a virtual reality system, combining recreation with exercise .

RESEARCH

Psychological and Physical Effects of Isolation and Confinement in Long Duration Space Flight

Confinement often causes crew members to feel that the area they occupy is smaller than it actually is. Therefore, the illusion of spaciousness should be incorporated in the design of rooms of the station. Using light colors for the surroundings, and strategically implementing windows are some of the techniques that will help accomplish this goal (Harrison, Clearwater & McKay, 1989). Provisions for the crew member that wants to "get away from it all" also requires consideration in the design. Chris McKay, who has "wintered

over" in Antarctica and is familiar with isolation and confinement, emphasized this point. During his expeditions, there were many instances when he would go to his tent in an effort to be alone. Even though he could not see anyone, he still heard the voices and radios of the rest of the crew. Designing a room that isolates the user from the crew may aid in creating the illusion of more living space, as well as provide an escape for the astronauts during their missions.

In an isolated and confined environment, it is not uncommon for the crew to become short-tempered with one another; especially in high stress situations. This is due, in part, to the fact that these crew members have been separated from their original social groups and placed together for a long period of time in a dangerous environment with limited living space (McKay, 1988). In order for the crew to maintain a healthy attitude, some form of entertainment must be provided (Clearwater, Coss & Bennett, 1989). There are a variety of ways to accomplish this task, including passive, interactive, active, and solitary entertainment.

Entertainment in which the crew member does not come into direct contact with other people is considered passive entertainment. Earth cues seem to be the most effective form of passive entertainment. Studies show that pictures of natural Earth scenes may actually decrease the level of arousal in people, reducing stress caused by confinement. These photographs, when hung on the walls, imitate windows and actually appear to increase the size of the room. Astronauts and Cosmonauts alike desire reminders of Earth, as both groups enjoy peering out of orbiter windows at Earth (Clearwater, Coss & Bennett, 1989). The Russians have employed a "psychological relief room," consisting of ten-minute wilderness films, slides of Earth, and accompanying music (Clearwater & Coss, 1989). Earth cues can also be supplied through the auditory system, with or without visual cues, by producing sounds such as a river or animals.

Interactive entertainment involves the interaction of the crew members through direct communication and/or contact with other people. The most popular form of

interactive entertainment among astronauts is conversing with others on Earth by 2-way radio. The Russians use a concept called "Videothèque," which allows crew members to speak with people and see them at the same time (Connors, Harrison & Akins, 1985). Feelings of isolation become less of a problem when crew members are allowed to communicate with people back on Earth.

Exercise (active entertainment) can also supply a physical and mental release not present in other forms of recreation. Studies of Navy crewmen show that exercise can help to maintain a healthy attitude in isolated and confined environments (Stuster, 1986). Since not everyone will want to exercise, the crew will probably need to be motivated to exercise. Competition is an effective way to motivate some people to exercise. However, when isolated and confined, some crew members react adversely to competition within the group. Their attitudes may tend to degrade teamwork, impair judgement, and occasionally lead to hostility. Crew members could compete against those on Earth to avoid inter-group competition, while still motivating them to exercise (Connors, Harrison & Akins, 1985). For those who do not wish to compete with others, self-improvement could be the driving force (Stuster, 1986). Our research has led to the conclusion that competition should be an option, but not mandatory.

In addition to the psychological reasons for exercise, there are also two physical purposes: 1) to minimize the deconditioning effects of reduced-gravity; and 2) ensure that the crew members will be fit enough to perform their required duties, both at the station and when they return to Earth. The deconditioning effects from reduced-gravity are the most important. At reduced-gravity, a person's body is not "strained" as much as in Earth's gravity, so the body tends to deteriorate and lose what it does not need or use. This loss affects the physiological and cardiovascular characteristics of the body. The primary physiological effects that are seen include decreased muscle mass (atrophy), strength loss in both the skeleton and muscles, a decrease in bone density, and a decrease in overall mobility (Converting, 1985). The primary cardiovascular effects are a decrease in oxygen

intake to the lungs when exercising, an elevated resting heart rate, and an overall decrease in the flow of blood to all parts of the body (Converting, 1986).

Entertainment Methods

Methods for providing recreation through visual means during exercise can be accomplished through two methods: using two-dimensional cathode-ray-tubes (CRT) or virtual reality. A CRT could be used to supply forms of entertainment, ranging from showing movies and TV shows to displaying pages in a book. Perceptronics, a company which manufactures CRTs for this purpose, has been marketing them to gymnasiums around the country for use with exercise equipment (Furness, 1990). This method provides a more versatile means of entertainment than still-photographs.

Virtual reality (VR) consists of computer generated "worlds" displayed to the viewer through binocular goggles. The viewer is actually an active participant of the generated world, and since the images are generated continuously, the viewer is given the opportunity to change the scene by physical actions. This is accomplished by placing motion sensors on the equipment or body. One advantage of VR is that it is not limited to reality, as the participant can enter the realm of fantasy by causing things to occur in the computer world that cannot actually happen in the real world, such as walking through walls or flying.

Auditory signals accompanying a visual display can increase the entertainment value. Possibilities range from loudspeaker systems to personal sound systems transmitted monaurally, in stereo or through 3-D sound imaging. Three-dimensional sound imaging is a means of transmitting sound more realistically. As the listener's location changes with respect to the source, sensors mounted to the head allow the sound that is heard to vary in location. So, if a plane is up and to the right, that is where the source of the sound would be perceived.

EXERCISE/RECREATION FACILITY

Constraints of the Facility

In order to design an exercise/recreational facility for extra-terrestrial habitats, several constraints must be satisfied. These constraints involve the environmental conditions of the habitat, size limitations of the facility, and other possible uses of the facility. An Earth-based simulator will help ascertain valuable information about the requirements of the facility, such as size requirements, isolation effects, optimal equipment arrangement, and overall fitness improvement. An Earth-based facility cannot be completely operationally tested because it cannot simulate the reduced gravity conditions found on the Moon and Mars. The Moon's gravity is one-sixth that of Earth, and Mars' gravity is one-third that of Earth. Obviously, the lower the gravity, the more exercise will be needed to maintain proper physical conditioning. Therefore, the location and gravitational conditions are important considerations in the design of the exercise facility.

Another constraint in the design of the facility is the size of the components. Since all components must be shipped by way of a space vehicle, the facility will need to be as small as possible to reduce liftoff weight. However, the crew members must have enough space to freely exercise or they will feel hampered and will fail to exercise properly. Also, when considering maintaining a controlled indoor environment, variables such as temperature and humidity must be taken into account. The goal is to build a large enough facility so the crew members have adequate space to exercise properly, while keeping the size of the space to a minimum.

Identifying the Users

An important consideration in designing an exercise facility is knowing who is going to use the facility, and the kind of requirements they will impose. Basically, the people using the facility will be astronauts, technicians, scientists, and any other inhabitants of the station. There are two distinct types of people who will use the facility, those of a competitive nature, and those of a recreational nature. Both will have to be provided with sufficient motivation to exercise. The complete size and crew requirements are as yet unknown for the habitation of other planetary bodies. The current height requirements for astronauts and mission specialists are between 60 and 76 inches (Hargens, 1990). This provides an estimate of the height ranges of the crew members at the space station or Earth analog. Also, both male and female crew members working at the station should be provided with an adequate workout. As a requirement for comfort and safety, the crew members will be provided with sufficient room in order to get the optimal workout. To allow crew members to maintain proper fitness and a strong desire to exercise, a variety of equipment should be provided.

Equipment in the Facility

The equipment in the facility will be investigated in four sections:

- (1) the function of the equipment
- (2) the equipment requirements for use in space
- (3) the various muscle groups that will be used
- (4) the exercise machines available

Functions of the Equipment

The equipment in the exercise facility will primarily be designed to prevent, or slow down, the deconditioning effects of reduced-gravity. As stated earlier, reduced-gravity conditions affect both the physiological and cardiovascular aspects of the body. The equipment must be designed to improve both muscle and skeletal strength, and maintain certain endurance requirements. Muscle strength must be improved so that the muscles do not experience atrophy when exposed to reduced-gravity, and usually isometric, isokinetic, or isotonic exercises are sufficient for this (Woodward, 1984). The body needs to maintain its skeletal strength, which is accomplished through impact due to exercises such as normal walking (Woodward, 1984). However, walking in reduced-gravity does not impose as much stress on the body as walking in Earth's gravity, so the exercise machine needs to be designed to simulate the impact one would feel on Earth during exercise. Physical endurance obtained through constant exercising must also be maintained to ensure that crew members can perform duties requiring stamina. The equipment should be designed to provide an adequate cardiovascular workout. It is inadvisable to let the crew members' cardiovascular systems degenerate to the point where even mundane physical tasks cause them to become short of breath. One of the indicators of aerobic workload is the amount of oxygen intake into the lungs (Bungo and Johnson, 1983). A high oxygen intake, which is an indication of a good workout, must be accomplished during effective exercise. Also, the heart must be exercised extensively so that it can maintain proper blood flow to all parts of the body (Converting, 1986).

Requirements of the Equipment

The equipment in the facility must be durable, safe, entertaining, and compact. It must be strong enough to support the users, and to stand up to continued use by the crew members. The equipment must also have a long design life, and low maintenance hours

since the crew members will have more critical things to do than spend time fixing broken exercise equipment.

The second requirement is that the equipment is safe to use. The space station or Earth analog will have little manpower due to small crew sizes, and cannot afford to have a crew member disabled due to injury. The exercise equipment must be safe to use, and all crew members must be instructed on how to use it accordingly. These instructions should include simple sketches or explanations on how to use the equipment properly. All of the machines must operate within the natural range of motion of the human body, and should not have sudden stops or starts. Finally, the machines should be equipped with active safety features to ensure that the user is not injured while exercising.

A third requirement of the equipment is that it provides entertaining and realistic simulations and should also be expandable to allow for future changes in technology. In the future, VR capabilities should make large technological advances. The exercise equipment must be capable of adapting to these improvements. It should also be entertaining enough for the crew members to enjoy exercising. If the crew member enjoys using the equipment, he will be more likely to stick to a stringent exercise plan. The equipment should also be realistic enough to allow the crew members to temporarily "escape" from their confined quarters and reduce the effects of isolation and confinement.

A fourth requirement of the equipment is that it is designed to be compact and lightweight, while remaining safe and easy to use. The smaller the equipment is, the smaller the facility can be. Also, the equipment must weigh as little as possible due to transportation costs. As of now, NASA limits the weight of exercise equipment to 75 pounds to ensure that it can be transported on shuttle missions (Hargens, 1990).

Muscle Groups

When designing exercise equipment it is important to consider the muscle groups

that the equipment will exercise. For our study, the muscles of the body can be categorized into four main muscle groups: the legs, arms, back, and chest. The most important muscles, as far as deconditioning effects are concerned, are the muscles of the legs, particularly the hamstrings and calves, as well as the lower back. These muscles are important because they will be used extensively for everyday activities aboard the space station or Earth analog. Since the body does not weigh as much in reduced-gravity, these muscles tend to experience atrophy readily, and thus need to be exercised the most (Berry, 1988).

Exercise Methods

Extensive research was required in order to design equipment for the exercise facility. It was determined that both physiological and cardiovascular effects are both equally important when exercising at reduced-gravity (Hargens, 1990). Various types of exercises were investigated in order to determine which were best for physiological and cardiovascular workouts. Resistance and impact exercises were found to be the best for the physiological workout, and aerobic exercises were found to be the best for the cardiovascular workout (Tipton, 1983). Studies have shown that the tension and stretch developed and maintained by muscle fibers during resistance exercises are key factors in maintaining muscle mass. Also, aerobic exercises maintain a strong heart and promote the oxygen intake to the lungs.

Resistance/impact and aerobic equipment types were investigated because they were found to be the most effective for reducing deconditioning effects. Ideally, the best types of resistance exercises are those that deal with weights, such as a Nautilus machine. However, weights cannot be used effectively in space because of reduced-gravity conditions, so other means must be employed to apply resistance, such as elastic "stretching" and pneumatics. During Skylab experiments, astronauts used the treadmill

(impact and aerobic) primarily, and the stationary exercise bike (resistance and aerobic) (Tipton, 1983). The Russian astronauts used the treadmill as their only exercise machine until a few years ago. Today, athletes prefer using both the exercise bike and rowing machine (resistance and aerobic) to train. Other examples of equipment that athletes use are the stair-climbing machine and cross-country ski simulator. A combination of the treadmill, exercise bike, rowing machine, and Nautilus style resistance machine would be the most effective for minimizing deconditioning effects.

The treadmill is the basic exercise machine for maintaining skeletal strength through impact (Tipton, 1983). The primary muscles exercised are the quadriceps, calves, hamstrings, and gluteals. The treadmill also works the cardiovascular system, although not to a great extent because of the relatively slow speed of walking. The treadmill is slightly less effective in reduced-gravity conditions.

The stationary exercise bike is currently one of the more popular types of exercising machines. The muscles exercised by the bike are primarily the legs, but some shoulder and lower back muscles are also exercised. Besides offering a good physiological workout through resistance, exercise bikes provide a high aerobic workout because of the fast workout speeds (Tipton, 1983).

The rowing machine is primarily used because it works the chest, back, and arms simultaneously (Schwarzenegger, 1985). Like the exercise bike, this machine can also provide a good aerobic workout because of the amount of energy needed to overcome the machine resistance. This piece of equipment is also probably the smallest of the four, and is one of the easiest mechanisms to design. However, it would be difficult to view objects for entertainment purposes because of user mobility during the rowing stroke .

A Nautilus-type resistance machine is the most diverse of the four existing machines. Any of the four major muscle groups can be exercised effectively. This Nautilus-type machine is also the best for exercising specific muscles because it allows the user to effectively "isolate" particular muscle groups (Schwarzenegger, 1985). However,

this machine usually offers little aerobic workout and can take a great deal of space if many exercises are desired for one machine.

Overall, these four types of exercising equipment would be sufficient to maintain the body at its proper physical conditioning. All four of the major muscle groups can be exercised efficiently with the ability to provide different levels of strength versus aerobic conditioning. For example, the Nautilus-type workout station is an excellent strength conditioner, but lacks the ability to truly test the users cardiovascular system. The exercise bike is not a great strength builder, yet it provides a good cardiovascular workout. The selection of the exercise machines in the facility is based upon an adequate balance between the cardiovascular and physiological conditioning.

FINAL EQUIPMENT SELECTION

Exercise Bike

The objective of this project was to incorporate exercise with recreation, so an exercise bike with a virtual reality system was chosen. The exercise bike was chosen for several reasons. It provides an excellent balance of physiological and cardiovascular workouts, while keeping the entertainment prospects the most diversified. The rider is in a stationary, upright position most of the time, and is therefore able to do many things, such as watch a television screen, read a magazine, or look out a window. Biking is a form of exercise which will give the rider more enjoyment and a more realistic feeling. It will also be easier to incorporate VR in the design to give the rider a large variety of exercise experiences.

Virtual Reality System

A virtual reality system was selected to satisfy the entertainment criteria of the exercise bike. As described in the background portion of this report, VR allows for the simulation of a realistic biking experience on a stationary bike in a confined area. VR is a relatively new technology that restricts a detailed design for our bike. The main components that will be needed are a set of viewing goggles, ear phones, motion sensors, and an appropriate software package.

We visited the Virtual Reality Lab at the University of Washington to explore the current technological status of goggles and software packages. The goggles they had were manufactured by VPL. They were very light weight and small enough to be comfortable for the user to wear during an exercise session. One problem envisioned with the goggles is that they may fog up from the users perspiration during a strenuous exercise session. Some type of ventilation system could be added to the goggles to prevent this from happening.

Dr. William Bricken, University of Washington, explained the status of VR software packages during our visit to Seattle. He predicted that in five years, a manufacturer could supply NASA with the computer hardware and software packages necessary to accomplish the needs for this VR system. Our goal of the VR system will be explained in the following bike/VR/user interface portion of the report.

RIDING SYSTEM

The riding system consists of four major components: a bike, a tilting mechanism a braking system, and a harness. A riding system was developed that could simulate all possible riding situations, such as going up hills and banking around corners. The system was designed to have both pitch and roll, as well as a variable rolling resistance. The riding system is shown in Figure 1.

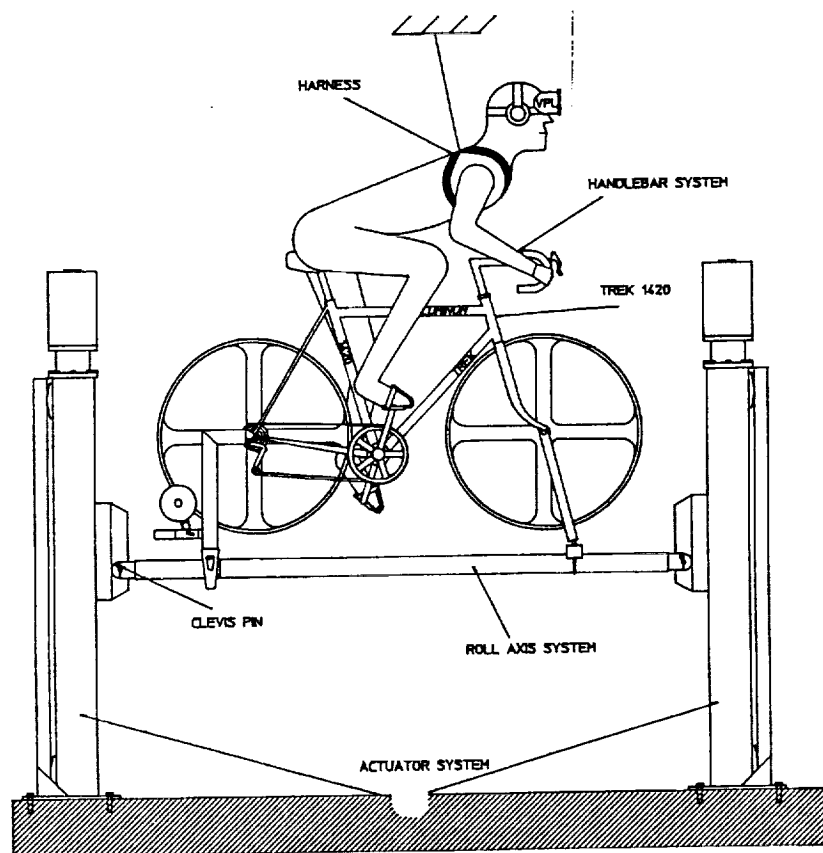


Figure 1, Riding System

The Bike

A non-ferrous bike, constructed of aluminium, was selected because the magnetic properties of ferrous materials interfere with the tracking mechanism used by the VR system. In order to simulate varied riding conditions, the bike needed to be versatile. The bike that was selected combined the performance qualities of a racing bicycle with the comfort of a touring cycle. The geometry of the bike was selected according to Military Standard 1472 to fit the height range requirement for the 95th percentile man to the 5th percentile woman. A Trek 1420, Aluminium, size 50, combination bicycle was selected because it fulfilled the above requirements (See Appendix A). In order to fit the 5th to

95th percentiles, adjustable handlebars and an adjustable seat were incorporated into the design.

Handlebar Assembly

A handlebar assembly that simulates both a mountain bike and a road bike will replace the handlebar assembly that comes with the Trek 1420 (Figure 2). This handlebar assembly will have brake levers and gear shifters that will be interfaced to the VR system. The handlebar stem will be inserted into the bicycle headset of the Trek 1420 (Appendix B). This will provide the typical steering rotation of the handlebars giving the user a very realistic feeling from a stationary bike. An adjustment feature will be added to the handlebars, since the bars must slide forward 20 cm to meet the anthropometric data requirements of the different crew member sizes.

1	CAMPAGNOLA C-RECORD HEADSET
2	MOTION SENSOR
3	QUICK RELEASE
4	GRP SHIFT PROLINE 1990
5	RITCHEY TRUE GRP
6	DIACOMPE XCE SHORT STOP
7	MOOOLO 8/X-TENOS
8	DURA-ACE BRAKE/SHIFT LEVERS

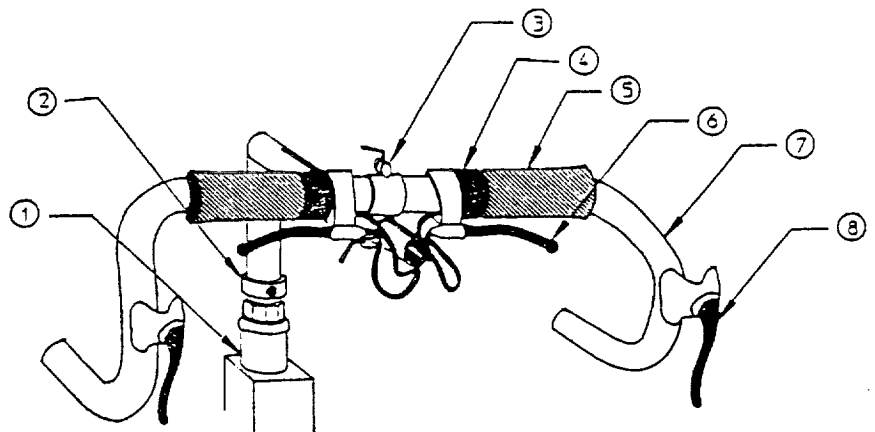


Figure 2, Handlebar Assembly

Tilting Mechanism

The bicycle is mounted on a tilting mechanism that provides both pitch and roll for the bicycle (Appendix C). The tilt mechanism consists of two actuators, a connecting bar, and supports. The actuators provide pitch by adjusting the height of the roll bar. The actuator system consists of two electric linear actuators mounted vertically. The actuators are driven by a 1 h.p. d.c. motor that will be mounted on the top of each actuator column. These actuators have a maximum throw of 3 feet, which allows the bicycle to reach a pitch of 25 degrees. A maximum speed of 10 in/s can be obtained by the actuators which will facilitate the simulation of hills and dips commonly encountered while riding.

The roll bar acts as the rolling mechanism for the bicycle and is connected between the two actuators. The roll bar is constructed of two pieces of aluminium tubing coupled to a telescoping section. This telescoping section allows the roll bar to elongate so that binding does not occur during pitch changes. Aluminium tubing is used because it is easy to machine, nonferrous and lightweight. The telescoping section is comprised of a heavy load spline nut, press fit into the aluminium tubing so that the bearing is fixed in one part of the tubing and the shaft is free to slide within it. The bike will be attached to the roll bar using a pillow block on the rear assembly. A ball joint assembly attaches to the front hub allowing a full range of motion for the crankset. This is desirable for both gyroscopic stability and riding simulation. The pillow block assembly attached to the rear hub allows the bike to roll about the roll bar axis, enabling the rider to simulate cornering in a more realistic manner. The bike will be stabilized by supports on the ground when the wheels aren't rotating and by the gyroscopic effects of the wheels when they are spinning, as on a real bike. A small motor will be attached to the front wheel to rotate it at the same speed as the rear wheel.

The support system holds the actuators in place. These will be attached to the floor

in order to provide the bike with a solid foundation, preventing any deflection between the bicycle and the actuator system.

Resistance Mechanism

The resistance mechanism was designed to replicate the rolling resistance of the bicycle as it travels over varied terrain, such as hills, dips, corners, etc. This will be accomplished by attaching a permanent magnet braking system, which provides a smooth, quiet, and efficient resistance. The braking system will be attached to the roll bar mechanism and a spring loaded link will hold the braking system against the rear tire of the bicycle. The resistance of the bike can be adjusted depending on the riding condition which is simulated during the VR session. This particular resistance mechanism was selected because of its low magnetic flux output and its ease of control using an analog signal.

Harness

The function of the harness for the riding system is to protect the rider from any accidents. If the crew member becomes overexerted and loses consciousness, no injury should occur (Appendix D). The main function of the harness is to prevent accidental falls from the bike. The harness was designed to be easily adjustable, comfortable, non-restrictive, easily put on and taken off, and strong enough to protect the rider. Therefore, a "figure 8" harness, similar to a rock climbing safety strap, was selected because of its unique quality of high strength without being restrictive and heavy. The harness is very easy to adjust to various body sizes and is not gender specific. The harness will be attached to a point above the rider by a cable fixed to the back of the harness. This will protect the rider from falls in the forward and lateral directions.

Bike/Virtual Reality/ User Interface

With the VR system, the user will be able to create whatever course is desired for the ride. It can be a mountainous terrain, a street course, or one of many other choices. Furthermore, three -dimensional audio imaging can be used to further enhance the rider's world.

The user's input to the VR system will be accomplished through petalling the cranks, steering the bike and using the brake levers and shifters in accordance with what is seen through the goggles. The system will be preprogrammed for each rider according to an exercise physiologist's prescribed work rate. If the rider falls below the necessary intensity, the VR may show an approaching hill in their riding world that must be climbed. A stronger current would then be signaled into the eddy brake, thus increasing the workload. If the rider is above the desired work rate, a gradual downhill stretch may appear on the VR screen, and a weaker current would be signaled to the eddy brake. The same thing can be accomplished by having the rider simply shift up or down. Shifting up would signal the computer to decrease the current in the eddy brake and increase the current when for shifting down.

This type of system would be very entertaining to use. It would give the astronaut a chance to forget about his isolated environment, break up a monotonous schedule, and reduce the undesired muscular and cardiovascular deconditioning effects which occurs in a reduced-gravity environment.

COST ANALYSIS

ITEM	PRICE
Trek 1420	\$700
Handlebars	\$1,000
VR Computer equipment	\$159,800
VR Headgear	\$54,640
Actuators	\$1,600
Motors	\$590
Resistance Mechanism	\$54
Miscellaneous	\$2000
Total	\$220,384

CONCLUSIONS AND RECOMMENDATIONS

This design accomplishes the purpose of creating both an exercise and a recreation facility. It will reduce the effects of deconditioning and the ill effects of isolation and confinement. With the virtual reality system and the tilt and roll feature of the riding system, the bike will be entertaining and realistic enough that the crew members should want to stick to their exercise plan. Since gyroscopic effects are not completely understood, the design may need some adjustments to maintain a realistic feel and to ensure the safety of the crew. Also, virtual reality is only in its beginning stages. As the technology in this field increases, the entertainment value and capabilities of our system will also increase.

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INTERVIEWS:

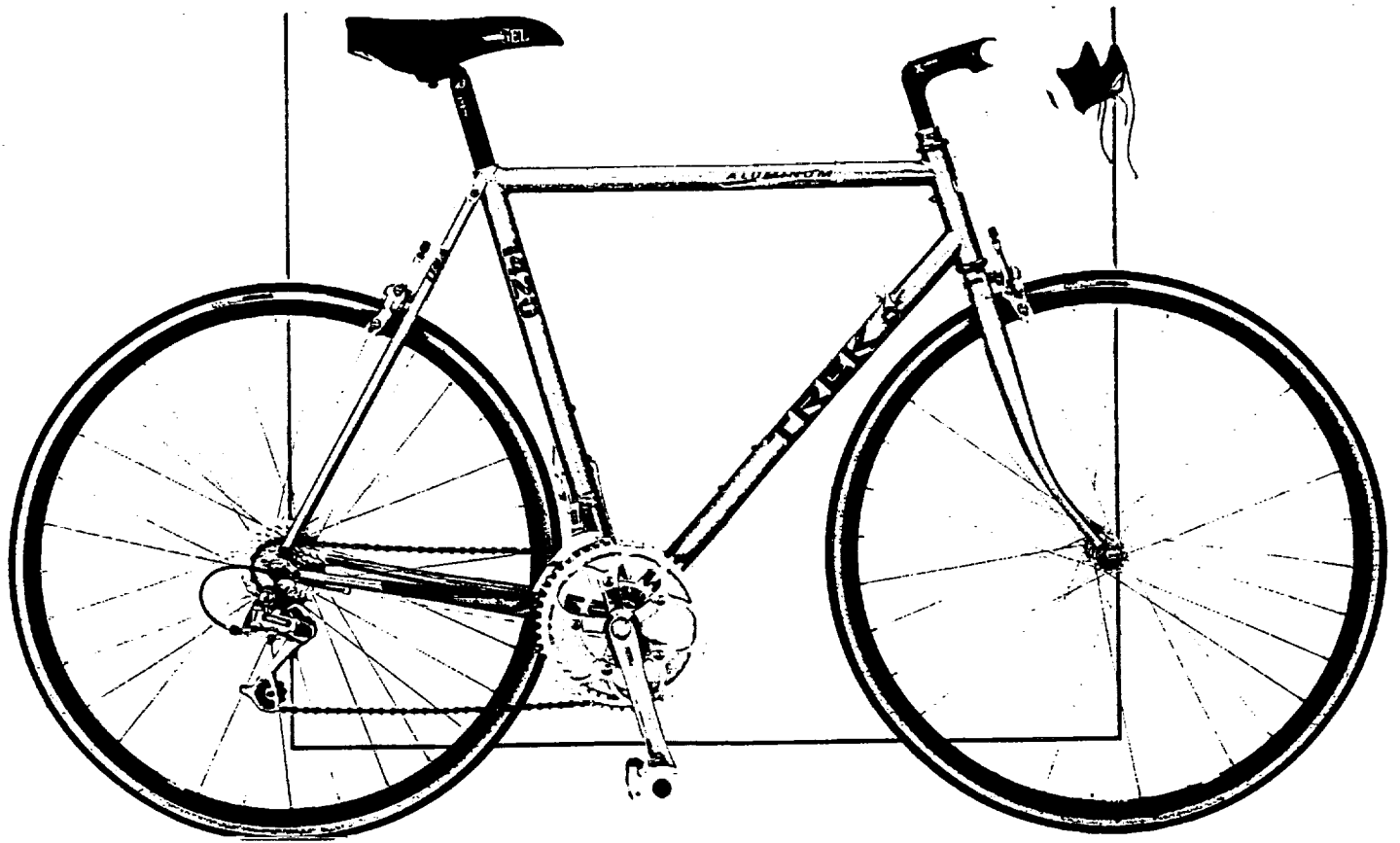
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APPENDIX A

Trek 1420

TREK 1420 SPECIFICATIONS

Components	Specifications
Size	50 cm
Frame	Easton 6061-E9 Double Butted Aluminium alloy bonded Aluminium
Hubs	Shimano 105, 32 hub with Quick-release
Rims	Matrix, ISO-C11, hard anodized
Tires	Matrix CD-3a 700X25C, Kevlar belted
Drive Train	Shimano Deore DX SIS
Brake Set	Shimano 105 SC Aero Super SLR
Freewheel	Shimano Hyperglide 12-28 7 speed cassette



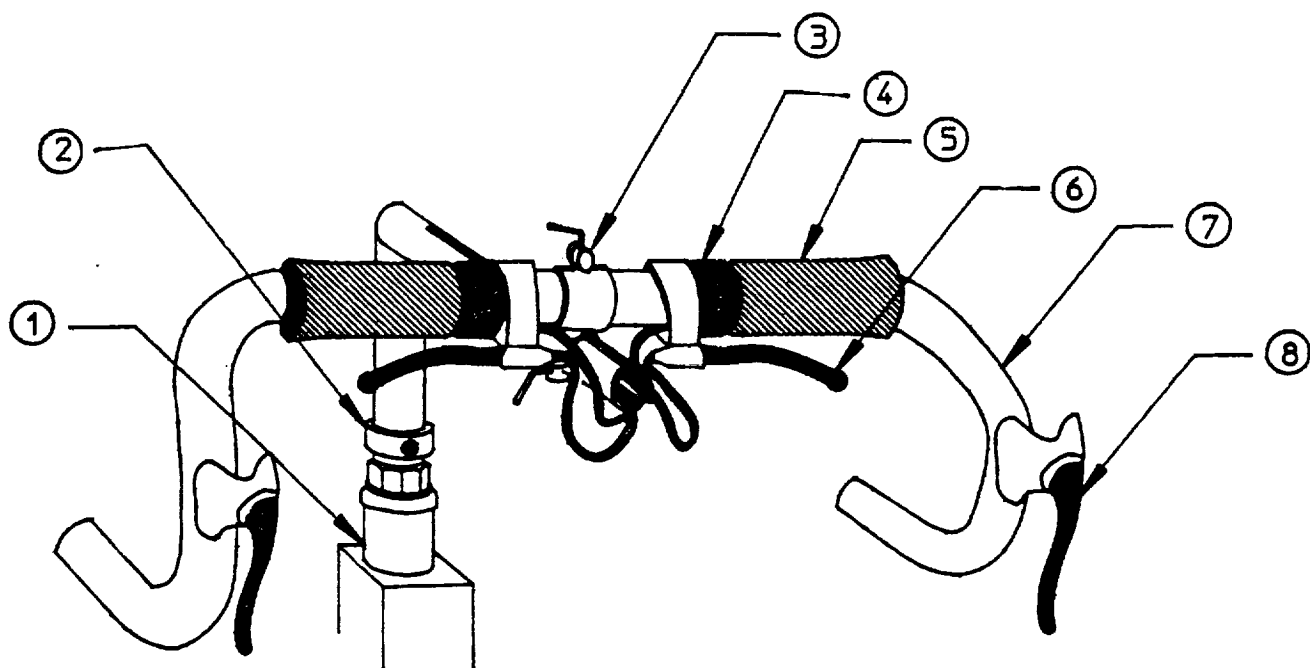
APPENDIX B

Handlebar Assembly and Mounting

HANDLE BAR ASSEMBLY SPECIFICATIONS

Components	Specifications
Headset	Campagnola C-Record Headset
Brake (inside)	Diacompe XCE Short Stop
Handle Bars	Modolo 8/x - Tenos
Grip	Ritchey True Grip
Brake (outside)	Dura-Ace Brake

HANDLEBAR ASSEMBLY



1	CAMPAGNOLA C-RECORD HEADSET
2	MOTION SENSOR
3	QUICK RELEASE
4	GRIP SHIFT PROLINE 1990
5	RITCHEY TRUE GRIP
6	DIACOMPE XCE SHORT STOP
7	MODULO 8/X-TENOS
8	DURA-ACE BRAKE/SHIFT LEVERS

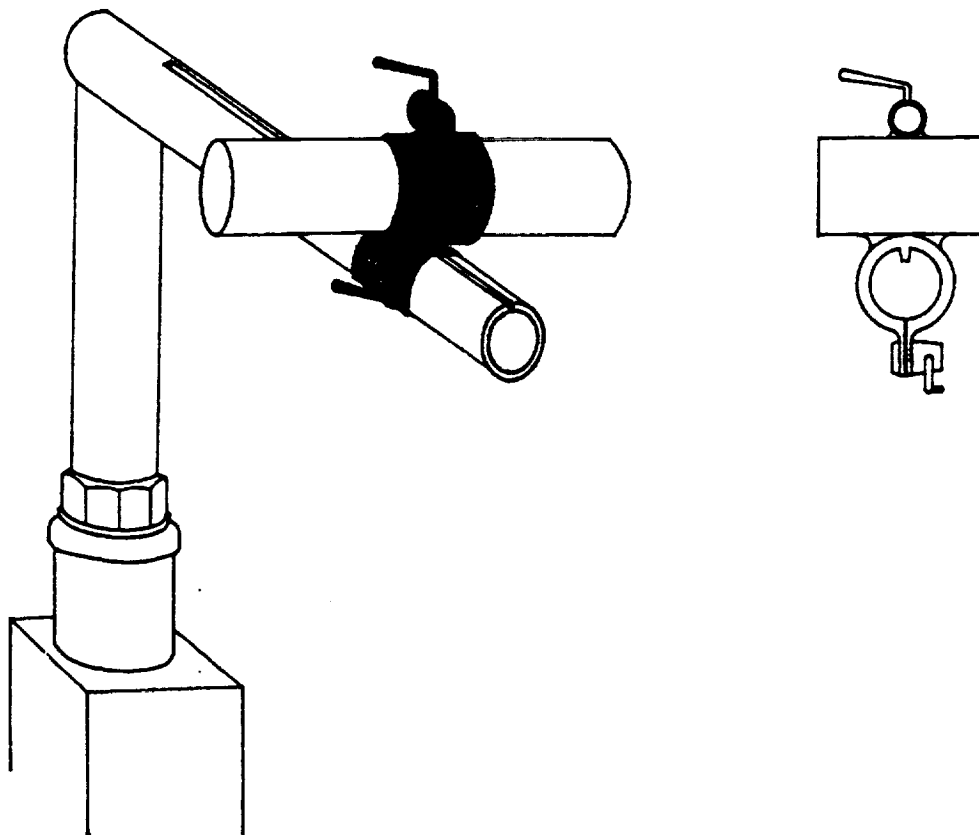
SIZE
A

NASA/USRA
UI DESIGN TEAM

NO
SCALE

DATE
12/17/90

HANDLEBAR ADJUSTMENT ASSEMBLY



SIZE
A

NASA/USRA
UI DESIGN TEAM

NO
SCALE

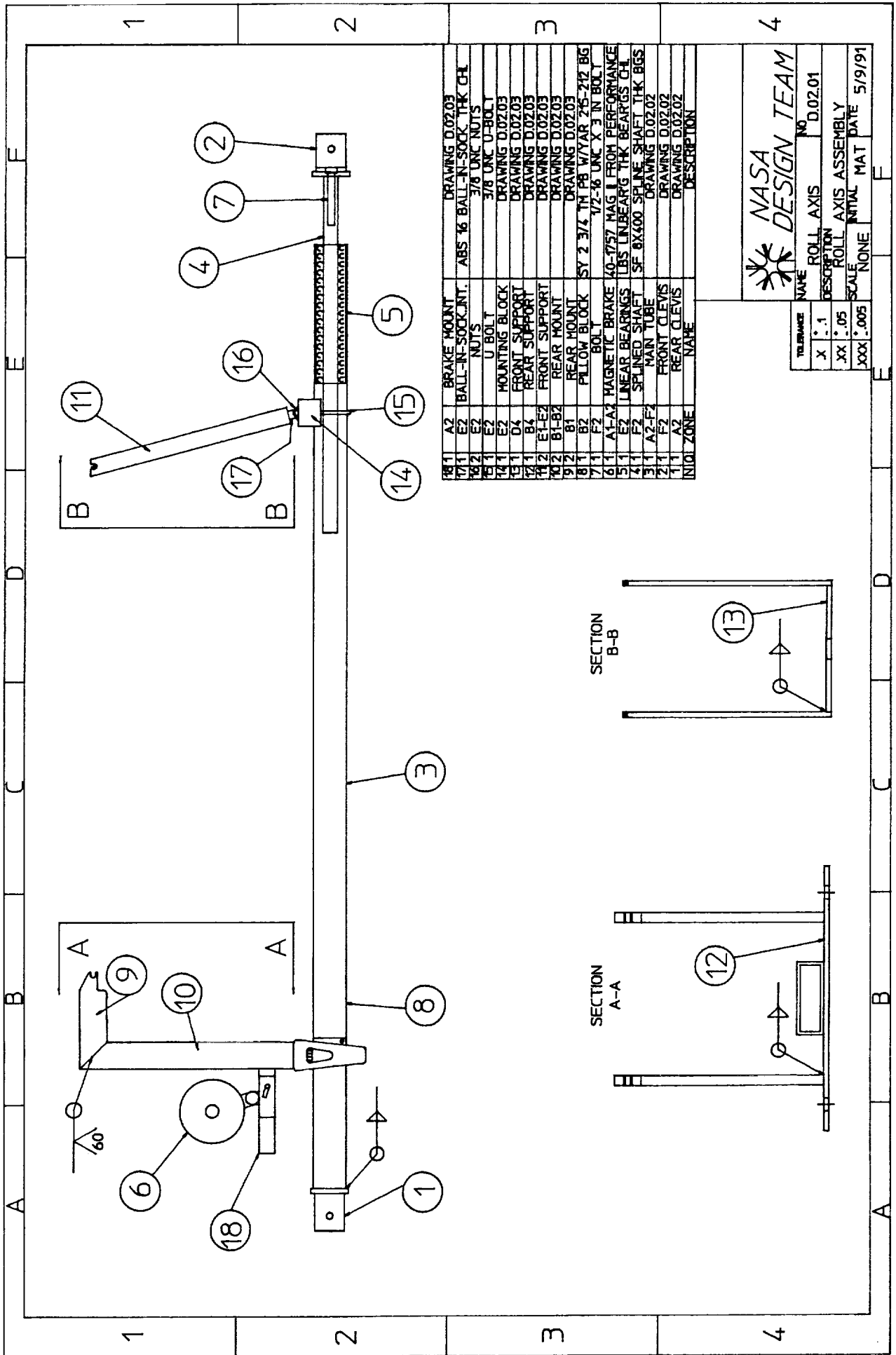
DATE
12/17/90

APPENDIX C

Tilting Mechanism

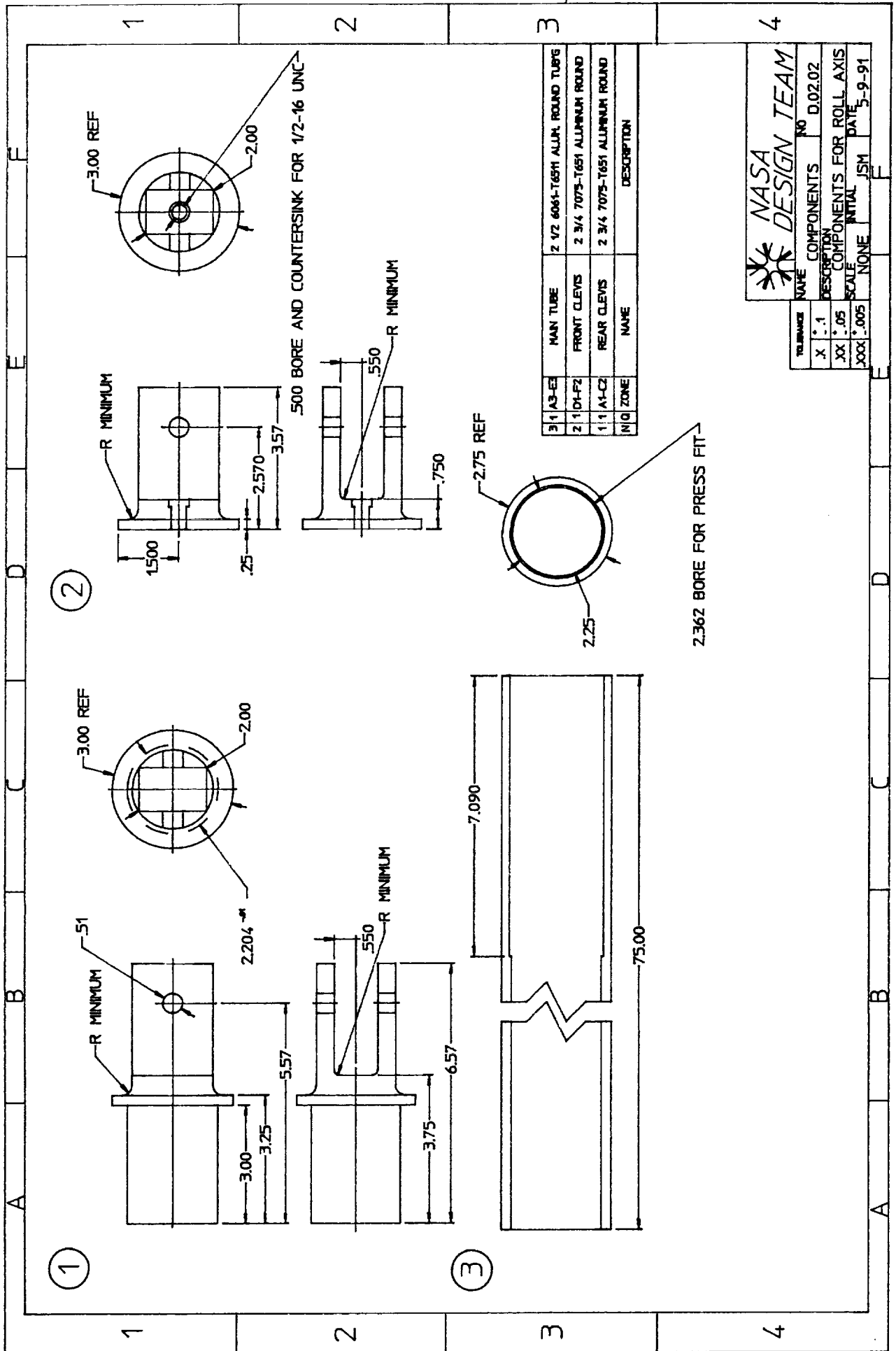
TILTING MECHANISM SPECIFICATIONS

Component	Specification
Roll Axis Tubing	1 x 1/8 6061 Aluminium Round Tube
Rear Pillow Block Bearing	SY 2 3/4 Tm Pillow Block with YAK 215-212 Bearing
Pin Joints	GR-12-SS McGill Precision Bearing Inc.
Actuators	TS 14 B 03 P Rapidtrak Actuator Warner Electric (Illinois)
Motors	1 h.p. M OH7211100 D.C. Motor SECO Seattle Wash



NO.	QTY	DESCRIPTION	UNIT	QTY	DESCRIPTION	UNIT
18	1	A2	BRAKE MOUNT			
17	1	E2	BALL-IN-SOCK JNT.			
16	2	E2	NUTS			
15	1	E2	U-BOLT			
14	1	E2	HOUNTING BLOCK			
13	1	D4	FRONT SUPPORT			
12	1	B4	REAR SUPPORT			
11	2	ELE2	FRONT SUPPORT			
10	2	B1-B2	REAR MOUNT			
9	1	B1	REAR MOUNT			
8	1	B2	PILLOW BLOCK			
7	1	F2	BOLT			
6	1	A1-A2	MAGNETIC BRAKE			
5	1	E2	LINEAR BEARINGS			
4	1	F2	SPLINED SHAFT			
3	1	A2-F2	MAIN TUBE			
2	1	F2	FRONT CLEVIS			
1	1	A2	REAR CLEVIS			
			NUT ZONE			

NASA DESIGN TEAM	
NAME	ROLL AXIS
NO.	D.02.01
DESCRIPTION	ROLL AXIS ASSEMBLY
SCALE	INITIAL MAT
DATE	5/9/91



NASA DESIGN TEAM

NAME	COMPONENTS	NO
X	0.1	0.02.02
XX	0.05	
XXX	0.005	

COMPONENTS FOR ROLL AXIS

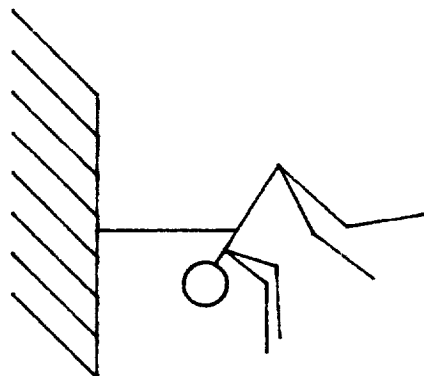
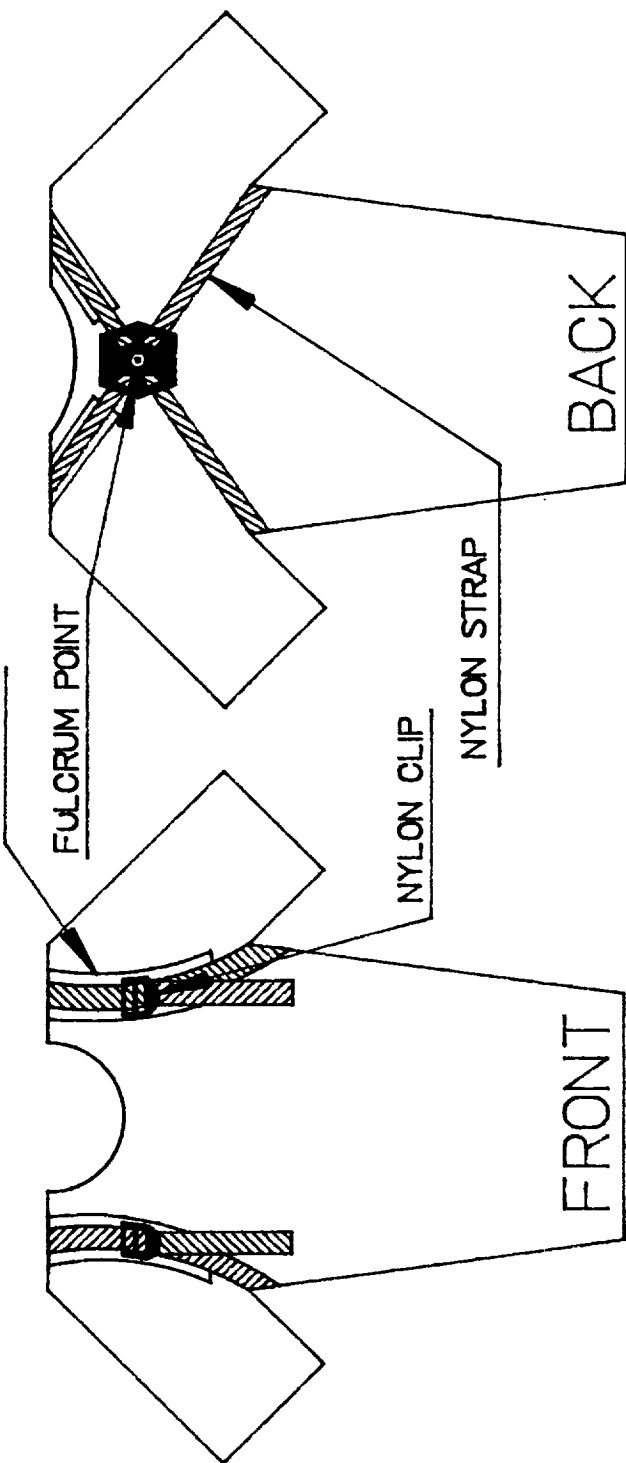
SCALE: NONE INITIAL: NONE DATE: 5-9-91

APPENDIX D

Harness System

THE HARNESS SYSTEM

PADDING



NAME	UPPER RESTRAINT	NO	1.02.01
DESCRIPTION	RESTRAIN RIDER FROM FALLING		
SCALE	NONE	INITIAL	DATE
		JSM	3-10-91

APPENDIX E

Calculations

CALCULATIONS

ACTUATOR CALCULATION:

Eccentric (moment) Loads:

Assumptions:

- (1) Designed for maximum load conditions.
- (2) Moment about the midpoint of the rectangular support.
- (3) Factor of safety of 1.7.

$$\Sigma M_O = F_{\text{down}} * MA_1 + F_{\text{horz}} * MA_2 \quad (\text{Equation G1})$$

where

M_O = Moment about the base point of actuator.

F_{down} = Downward force on the actuator support.

MA_1 = Moment arm.

F_{horz} = Horizontal force on actuator.

MA_2 = Moment arm.

$$\Sigma M_O = 190.07 * 9.6 + 93.84 * 41.32$$

$$\Sigma M_O = 5702 \text{ (in lbs)} * 1.7$$

$$\Sigma M_O = 9694 \text{ (in lbs) or } 75.85 \text{ ft lbs}$$

Calculation of stress assuming a flat piece of material.

$$\sigma_{\text{max}} = \frac{M y}{I} \quad (\text{Equation G2})$$

where,

σ_{max} = Maximum bending stress.

M = Bending moment.

y = Distance from the neutral axis.

$$\sigma_{\max} = \frac{9694 \text{ in lbs} * 1 \text{ in}}{I} = \frac{9694 \text{ in lbs} * 1 \text{ in}}{\frac{b h^3}{12}} = \frac{9694 \text{ in lbs} * 1 \text{ in}}{\frac{4 \text{ in} (2 \text{ in})^3}{12}}$$

$$(\sigma_{\max} = 13,932 \text{ psi tension})$$

Check square tubing:

Thickness = 0.125 in.

Dimensions = 1 3/4 x 4

Yield Stress = 25 ksi

$$\sigma_{\max} = \frac{M y}{I}$$

$$I = \frac{b_o h_o^3}{12} - \frac{b_i h_i^3}{12}$$

$$\sigma_{\max} = \frac{9694 \text{ in lbs} * 0.875 \text{ in}}{I} = \frac{9694 \text{ in lbs} * 0.875 \text{ in}}{\frac{b_o h_o^3}{12} - \frac{b_i h_i^3}{12}} = \frac{9694 \text{ in lbs} * 1 \text{ in}}{\frac{4 (1.75)^3}{12} - \frac{3.75 (1.5)^3}{12}}$$

$$(\sigma_{\max} = 11,587 \text{ psi tension})$$

therefore,

$$1.7 \sigma_{\max} < 25 \text{ ksi}$$

Conclusion:

Square tubing will withstand the stresses.

Total Force Calculation:

$$F_{\text{tot}} = F_a + F_m + F_{\text{acc}} \quad (\text{Equation G3})$$

$$F_{acc} = \frac{\text{Load}}{32.2 \frac{\text{ft}}{\text{sec}^2}} * \text{acceleration} \quad (\text{Equation G4})$$

$$F_a = \text{Load} \quad (\text{Equation G5})$$

$$F_m = M_a * 0.45 + R \quad (\text{Equation G6})$$

$$F_{tot} = 411.83 \text{ lbs}$$

Therefore, assuming that we drive the motor at 10 in/s and at an acceleration of $16.1 \frac{\text{ft}}{\text{sec}^2}$ then the motor required is a 1 h.p. D.C. motor.

Calculate maximum moment in order to call out telescoping bearing.

$$M_a = F * d \quad (\text{Equation G7})$$

$$M_a = 91.5 \text{ lbs} * 10.25 \text{ in}$$

$$M_a = 937.875 \text{ in lbs} = 119.3 \text{ N m}$$

Therefore, using a factor of safety of 1.7

$$1.7 * M_a = 202.8 \text{ N m} < 269 \text{ N m} \text{ (maximum permissible moment on bearing)}$$

Conclusion : Bearing is acceptable.